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Bruun-Pedersen, Jon Ram; Serafin, Stefania; Kofoed, Lise

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Simulating Nature for Elderly Users - A Design Approach for Recreational Virtual Environments

Jon Ram Bruun-Pedersen*, Serafin, Stefania**, Lise Busk Kofoed***

Dept. of Architecture and Media Technology
Aalborg University Copenhagen
Denmark

*jpe@create.aau.dk, **sts@create.aau.dk, ***lk@create.aau.dk

Abstract – Recreational nature experiences are rehabilitative for humans. Nature-oriented virtual environments (VEs) might be able to provide similar experiences. A pilot study have shown to increase the enjoyment of an exercise experience for retirement home residents, by augmenting their everyday bike exercise with a custom made recreational VE. This paper proposed a set of guidelines with design considerations that should be considered essential when designing recreational VEs. The guidelines combine considerations from tourism, urban and landscape design, psychology and VE navigation guidelines.

Keywords - Nursing home, Recreation, Rehabilitation, Virtual Environments, Design, Augmentation, Therapy, Guidelines, Elderly, Field Trip

I. INTRODUCTION

Virtual Environments (VEs) have been used for rehabilitation purposes for years, for example balance and stroke rehabilitation [1] [2]. VEs are able to provide a connection between real world actions and virtual world reactions, comparable to real world situations. They can provide safe testing environments for users who need a reality-like experience, with certain factors added, removed, or altered or under specific control in real time [3]. Virtually simulated situations can be tailored for untrained or incapable practitioners, as the VE simulation removes the real world consequences of inability or premature choices of action [4]. Augmentations through virtual technology can serve as a diversion, and redirect attention away from otherwise pain related exercises, relieving tension for example for elderly users during rehabilitation [5]. In a pilot study preceding this paper, Bruun-Pedersen et al. [6] showed how a simple VE augmentation of a manuped exercise was able to provide an improved experience over the conventional version of the exercise. The experience was recreational exploration of traveling along a trail in a nature-based environment. Results showed that 70% of the subjects wished to continue with the augmentation [6]. However, subjects also expressed a necessity for improvements to the VE design, in order to maintain interest for longer periods of exposure. Future implementations would need a variety of VE locations, with larger and more complex designs. This paper looks at interesting design considerations for recreational, trail- and nature based VEs to obtain useful design guidelines, and discusses it in reference to its application for elderly users.

II. BACKGROUND

From a psychological perspective, humans connect to nature surroundings and nature experiences [7]. Even through a window, nature-based stimuli produce relaxation and wellbeing [7]. Depledge, et al. [8] describe how humans have a health related link to nature. Nature experiences can reduce stress, recover attention capacity and cognitive functions. The authors suggest that high-fidelity VEs should be able to produce similar effects, especially through multimodal stimuli. This could prove useful with medical recreational purposes for elderly or hospitalized individuals [8]. Kort and Ijsselsteijn [9] use the term *restoration* to describe the same effects from natural environments. To promote physical activity with elderly users, consumer products such as the Nintendo Wii have been popular [10], but subsequently been questioned as dedicated physical therapy devices [11] [12]. The reason is, that serious physical therapy devices need to be tailored for unique user groups such as elderly users, also depending on the level of assistance available [13] [14]. At nursing homes, physical therapy must conform to how body strength, balance, flexibility, motor functions, and cognitive abilities are very limited with most residents. As a consequence, complexity, speed, strength and cognitive requirements for physical therapy must adapt accordingly.

A pilot study by Bruun-Pedersen et al. [6] tested the concept of augmenting an exercise action with a recreational trail-based VE exploration, for nursing home residents. Due to the limited abilities in both physical performance and interaction complexity of this user group, the interaction design was limited to the familiar movements of a conventional manuped exercise routine (pedaling with arms and legs). In the study, the VE experience consisted of a small trip around a lake, in a countryside environment. The goal of the pilot study



Figure 1: Pilot Test in [6] used a countryside VE

was to test if the users would accept the augmentation, if the inclusion of a VE augmentation changed their exercise experience, and why. Results showed that the augmentation was able to contextualize the pedaling actions to the VE trail. The VE created a sensation of purpose to the exercise actions, by the sensation of moving forward and to experience travelling and exploring another place than the nursing home. The augmentation gave some subjects an experience of otherwise lost efficacy, by being able to “move themselves forward without assistance” from nursing home personal. Being exposed to nature-based “beauty” was given high praise, as the overall theme for the VE. It was clear that the augmentation resembled a recreational nature experience for many subjects. From the post-exercise interview, objects that had made a significant impression were the few houses and a large willow. Additional environment content such as trees, water and green grass, or features such as sunny day colors all supported the overall positive impression of the VE [6].

The level of fidelity of the VE’s nature experience also showed indications to be sufficient (as most subjects thought the VE display to be authentic video footage), and overall, the continuation of the work was encouraged by 70% of subjects in the pilot study. However, results also showed a necessity for improvements to the overall VE design approach. There should be an increased diversity of VE content, with a stronger environment “identity”, through a more accomplished consistency between types of trees, foliage, constructions, etc.). A larger variety of VE locations and more “life” (for instance animals, wind, running water) were encouraged, in order to increase enjoyment and curiosity with the users, in addition to sense of realism, surprise elements and thus longevity for the VE [6]. The pilot VE was built with little to no clear design method besides intuition and a few reference photos from Google, and depended on the availability of countryside oriented 3D assets for Unity3d. As such, the pilot study both suggested that a VE augmentation could work for this purpose, for this user group, as a recreational experience focusing on the wonderful potential of nature experiences. But also that very close attention should be placed on the design of the VE, due to its role as the main contributor of content for the overall experience.

A. Content necessary for recreation VE

In many studies on VE rehabilitation, the VE simply provides ambience for a primary task in close proximity to the user in the VE, such as often the case for mini-games or task solving for motor rehabilitation, often with no need for ecological considerations to the design [15] [16] [17]. Closer related are behavioral studies focusing on real world environment replication into VR [3] [18] [19], where the VE is the main communicator of information and has to be convincingly rigorous in its inherent content, structure and detail to produce a convincing experience. In the VE exercises from Nurkkala, et al. [19], some of the VEs are replica and some are custom, but despite the VEs being the main attraction of the installation, the paper presents no reasoning behind the requirements to the individual VE design. Lange [20] describes the development of detailed 3D environments as labor-intensive, and discusses where the perceptual limits could be,

to get the best realism-to-workload ratio. VE replications from real world environments require documentation (i.e. often requiring travel), detailed mapping and 3D modeling, etc. [3]. However, VEs based on real locations have the major advantage of already being fully designed, and thus being ecologically “perfect”. Custom VEs are initially blank canvasses by comparison, and should be designed with knowledge of which criteria are relevant to be a convincing experience. Kort and Ijsselstein [9] suggest that multimodal VEs do not need photorealism to achieve convincing realism, due to top-down cognitive processes involved where vision only plays a part in a convincing realistic experience [9]. Lange [20] quotes Hall [21] concerning how correct imagery and geometric detail are not direct requirements for the impression of realism, as long as the behavior is reasonable. High image complexity and subtle shading and surface detail are central when creating the perception of realism [21].

Depledge, et al. [8] insist that *content* is a most critical issue, for ensuring engaging and immersive properties of a VE. For recreation-purpose VEs, exposure to water and forests visuals and outdoor environmental sounds should be considered, along with natural colors such as greens, blues and browns. Sounds from birds, water and wind, odors and air movement all contribute to this as well, with *water* being especially important. However, the presence of other human beings might ruin the effect [8]. Koenig, et al. describe their requirements for ensuring the recognizability of their real world office environment replication in that it requires enough environment details (furniture, etc.), high quality textures (to aid orientation), correct scaling of objects and realistic lightning. To ensure this, documentation through media of similar environments remain a valid way to analyze and find key identity elements for realism characteristics [20].

For nature experiences, Dorwart, et al. [22] examine the perceptions and preferences of visitors of Great Smoky Mountains National Park trail based recreation tours, proposing a model for evaluating the nature-based recreational experiences [22]. The “Nature-Based Recreation Experiences” model include five themes of trail environment elements, where three *nature-oriented detail*, *scenic values*, *management influences* and *depreciative behavior* are related to the representation of the natural environment, an *presence of others* relate to the presence of other people in the environment [22]. For the National Park, *nature-oriented details* is the dominant theme, with positive reports on the appreciation of small details, for instance from plants and a green carpet of such vegetation, wildlife, to be surrounded by vast forest, rock-formations, and generally combinations of natural elements. Positive *scenic values* include high altitude vistas, overviews of trees and scenery, beautiful views, and light and shade combination. *Management influences* refer to maintenance of e.g. stairs, shelters, and other constructed elements to help the experience of nature. *Presence of others* relates to sharing the experience, and *depreciative behavior* is when people are not respecting the environment by leaving litter, trash, destruction, etc.) [22]. The trail itself need to blend in with the natural setting to keep the trail visually compatible to the surrounding

environment, and curve if attention needs to be placed on the trail itself or trail elements. Other points of interest are beautiful vistas and natural elements, such as waterfalls. However, Dorwart, et al. [22] do stress how such results are heavily influenced by the individual's perception, preference and experience of each subject.

B. Navigation Guidelines to manage content

According to Vinson, content structure through a classification of distinctive environmental features, affords navigation proficiency through both large-scale real and virtual environments [23]. It's a reference point placement design framework, which is mostly oriented towards aiding a user's overview while navigating freely in a VE. It is meant to maximize recognizability, the user's sense of position in the VE and develop the user's mental representation of the VE. In a trail-based VE exploration design, where an exciting experience might be based on the element of surprise, Vinson's framework might seem contradictory. Meanwhile, the pleasantries of the exploration experience should come from the presence of interesting and pleasing content, and placing it cleverly does not automatically make it repetitive. Reference points, generally referred to as *landmarks*, ease the cognitive load and free resources for other perceptions or decisions while traveling a VE. An increase in recognizability of different VE locations could serve the memorability of the VE experience for nursing home users, who often suffer from a degree of dementia. Any user's knowledge of the VE is likely to have distortions. Landmarks minimize the risk of such distortions, and VEs should strive to contain several.

Landmarks are objects distinct from "virtual objects", which is what Vinson calls all landscape features and content [23]. Landmarks aid the user's interpretation of how to navigate the VE, through their distinction from virtual objects. Different types of landmarks serve individual purposes; *paths* (such as streets, canals) are channels for movement, *edges* (fences, rivers, etc.) indicate district boundaries, *districts* (neighborhoods) are reference points, *nodes* (town square, public buildings, etc.) are destinations for travel, and *landmarks* (such as statues) are reference points impenetrable for travel [23]. Individual landmarks need to be sufficiently distinct and unambiguous to make them uniquely memorable through detail variations such as height, shape, etc. and ensure that they are distinguishable from their surroundings [23]. Man-made landmarks are easily remembered, while virtual objects are less reliable. Landmarks should be considered in all viewable sizes in the VE, for different layers of VE position reference from a viewing distance. Landmarks should be placed along major paths and in junctions, as these provide identity to the landmark (and therefore place on the path). There should be a balance to landmark placement, and ideally two landmarks should be visible at any time. To ensure a spatial relationship between individual landmarks, these should ideally be structured in a top-view map overview. Vinson [23] recommends that paths resemble a *grid* (for navigation overview). But for recreational VEs, a grid based forest path could be argued to remove the nature-based organic sensation. All in all, the approach of the landmark typeset is a valuable combination of a top-down and bottom-up design approach.

III. METHOD: RECREATIONAL VE DESIGN GUIDELINES

From the reviews in the previous section, we found many relevant considerations for recreational VEs, ranging from quite specific items, to technical considerations, to broad recommendations or guidelines. In this section, we propose some *Recreational VE Design Guidelines* in which we organize the review findings into two central categorizations; *Recreational VE content* and *Recreational VE features*. During this section, we will regard several considerations about recreational VE design from these main categories, whose main purpose is to structure and increase clarity on how to approach specific necessary characteristics of a recreational VE. We chose to present the two categorizations in relation to their useful application within the typeset of *landmarks*, and how some aspects of the categorizations play an important role outside of the landmark typeset. The chapter presents two pairs of tables, each pair representing one of the two main categories, split into considerations applicable to a) the landmarks typeset and b) other relevant factors found in literature.

Before addressing the tables concretely, it needs to be said that they retain a generalist approach to their message, in the sense that they don't target a specific VE design. Therefore, when e.g. types of content are represented, it leaves it up to the individual design team to determine the specifics of what constitutes the appropriate and specific items to represent the individual VE's core identity. In other words, a mountain VE would contain different natural items than a tropical jungle, etc.

In terms of how the tables are set up, they place heavy focus on the *landmarks* typeset. The motivation for this lies in the previously explained ability of landmarks to provide a structural approach to placement of VE content. Landmarks should be considered useful allies in any VE design, in terms of their ability to increase a designer's understanding a VE's individual parts, and in turn increase the probability of the user's ability to recognize the individual areas of the VE. The *Recreational VE content* (as shown in Table 1) outlines the parts within the recreational approaches in the literature review that fits within Vinson's definition of the landmark types.

Common for the *Recreational VE Content* representing each landmark type in Table 1, it's mostly represented by various human type influences to a landscape. Landmarks should predominantly be man-made. In a nature environment, it makes them stand out, but in addition, man-made objects do not rapidly change appearance like many natural objects (bending, wind, growth, decay, or other inconsistencies in appearance). While this is sensible, most work reviewed in this paper finds essential VE content for recreation to be nature oriented and non-human based, with a common emphasis on how man-made objects should be kept to a minimum or at least be well maintained. In that sense, Table 1 shows only VE content found that fits into the prescriptions from Vinson [23].

Table 2 shows recreational VE content found from non-landmark content represented in the review literature. Vinson [23] uses the term *Virtual Objects* for landscape content items of the VE that are not landmarks. This category holds many of the literature findings deemed to be recreational VE content. Different from what Vinson focuses on in his use of landmarks

as navigation tools, for recreation, Virtual Objects are environment content that defines much of the VE identity, by forming the backbone to the otherwise useful landmarks. For recreational purposes, the reviewed literature shows that virtual objects hold a lot of the value of the recreational experience. Landmarks should be remarkable, and definitely able to be defining parts of the VE experience, but without the virtual objects, the landmarks would be “naked” objects without context. Therefore, virtual objects are both very necessary as supporting content for the individuality of the landmarks, but also represent much of the essential recreational VE content.

The same type of VE content can represent different types of landmarks and vice versa, by the role it plays in the VE, as for instance shown through which type of landmark the given content represents in a given situation. A “trail” can be a path, but it can also represent an edge. It can be part of a node’s functionality (for example giving an view of many trails in the distance), but at a later point, the user might be positioned in the spot that previously represented the view given by the node.

Landmark Types	Examples of Recreational VE Content
Path	Trail [6, 22, 23] Man-made objects [23] Maintained human objects [22]
Edge	Water [6, 8] Trail [6, 22, 23] Man-made objects [23]
Node	Houses [6, 23] Public/official structures or spaces [23] Man-made objects [23] Maintained human objects [23] Waterfalls [22]
Landmark	Man-made objects [23] Maintained human constructions [23] Waterfalls [22] Statues, monuments etc. [12]
Junction	Trail [6, 22, 23] Man-made objects [23]
District	Specific combinations of virtual objects and landmarks [23] Neighborhoods 9 [23]

Table 1: Overall considerations for content types that literature suggest for recreation, which fits the individual landmark types.

Non-landmark Items	Examples of Recreational VE Content
Virtual Objects	“Green carpet of vegetation” [22] Grass, plants, trees, “greens” [6, 22] No litter, etc. [22]
“Life”	Running water [6, 23] Wildlife [6, 22] Air movements [8] Outdoor environmental sounds (air, birds, water, wind, etc.) [8] No humans [8, 22]

Table 2: Overall considerations for content types that literature suggest for recreation, ranging outside conventional landmark types.

Trail-based, recreational VE designs need high diversity in the VE content, and often have numerous objects combined to a larger whole. An overall consistency, with a consciously set of content items is important, to create and maintain an environments’ identity. Varied documentation (photos, video, etc.) is central for ensuring such identity. Rich surface and geometric detail, as well as high quality textures add important visual fidelity, and high environmental complexity in various forms is a priority, in micro and macro perspectives. This signifies well what Table 3 and Table 4 represent, as the features that should be considered for the content represented in a recreational VE.

Landmark Types	Examples of Recreational VE Features
Path	Surface detail [22] Small details [22] Blending into the VE [22] Nature-based surface [22] High quality textures [18]
Edge	Surface detail [22] Small details [22] Blending into the VE [22] Nature-based surface [22] High quality textures [18]
Node	Visual consistency between elements [6, 18, 22] High altitude vistas [22] Beautiful vistas [8, 22] Overview of parts of VE [22] Depth cues [22]
Landmark	Variations in height, size, form [23] Surface detail [22] High quality textures [18]
Junction	Surface detail [22] Small details [22] Nature-based surface [22] Blending into the VE [22] High quality textures [18]
District	Visual consistency between elements [6, 18, 22] Nature [6, 7, 8, 9, 22] Forest visuals [6, 8, 22] Water [6, 8] “Green carpet of vegetation” [22]

Table 3: Features that given landmark types should accommodate.

Non-landmark Items	Examples of Recreational VE Features
Virtual Objects	Visual consistency between elements [6, 18, 22] Natural colors [8] Surface detail [22] Small details [22] Reasonable behavior [20, 21] High quality textured [18] Correct scaling [23]
Other considerations	Varm lighting [6] Subtle shading [20, 21] Realistic lighting [18] Light/shade combinations [22] Multimodal display [6, 9] High image complexity [18]

Table 4: Features that non-landmark type content should represent.

So while the *Recreational VE Content* relates to the types of objects to place, the *Recreational VE Features* relate to how either technical or artistic qualities play a large role in the presentation of the VE content, landmark or non-landmark. As a large-scale VE should be based on several *districts*, each individual district should have unique characteristics. Many of these are found through the Recreational VE Features, from a degree of variance between landmarks and virtual objects (along with the “life” factor). This forms the chosen identity of the district, as well as (districts collectively) the VE. On a different perspective, each of these entries in the VE has unique roles to play, according to the perspective of use in a given situation. *Nodes* for instance, grant possibly beautiful vistas is important for trail-based VEs, creates a sense of scale as *depth cues* to both near and far VE elements, and possibly even give hint to several other *districts*, which for instance was a central experience of a mountain-based environment [22]. It is here that the landmark-oriented approach is well used as a mapping approach. A depth-enhancing *node* as a beautiful vista can be planned very easily, and ensure that it plays well together with other landmarks, as well as the virtual objects, etc., also for its role as a recreational feature of the environment. Such angles open the designer to a creative approach within a specific terminology-based rule-set, either in a top-down or bottom-up process, depending on the phase of the design. A top-down approach should prove beneficial in the initial planning stages of the VE, as well as any mapping and overview processes. A bottom-up approach should prove useful when testing the role of already placed VE content, relative to their landmark type and role. The use of a *grid* to form paths and outline districts in a simple form, to reduce distortion is recommended by Vinson [23]. While block-like path grids are an obvious representation of natural environments, the idea of using a grid to overlay a VE map top-down, should be a more systemic way to balance the distribution of landmarks, as well as identify their individual roles.

IV. DISCUSSION

This paper proposes an overview of considerations to form a set of guidelines for creating custom-built VE designs. The background review takes its reference in many different areas, ranging from VE designs that copy real world environments, to results from tourism, based on user experience preference data derived from real world recreational trail hikes. The paper also shows how some attempts to make custom built VEs seem to have been made without a clear design approach, which leaves the question of whether a higher quality VE could have been obtained, had they been given a structured design approach. Depledge, et al. [8] state that content is essential, but it’s hard to neglect the relevance of how such content is constructively placed or functionally positioned in an environment, especially considering VEs that are not 100% based on real environments references. To use the landmark typeset from Vinson [23] and apply them usefully but in a slightly different role, is an interesting exercise in using the merits of something, with an alternative application purpose.

Besides the alternative view on the relevance of landmarks, the way these Recreational VE Design Guidelines propose a separation into categories of (recreational) *VE Content* and *VE Features* is another way of proposing the necessity of looking

at VE design in a multifaceted fashion. That a specific content type is relevant in a specific VE is a good entry-point, but the representation of this content is something that should vary depending on the purpose of the overall expression of the VE design. For recreation purposes, literature speaks a clear language in terms of how the recreational content needs a distinctive amount of detail, realism of lighting and complexity in its composition, to create due to its purpose of being inherently interesting in itself.

However, much of this depends on the user group who is to receive the experience. In this paper, the guidelines have taken in references from the pilot study from Bruun-Pedersen, et al. [6] to affect the content and feature guidelines of a recreational VE. From the study, it was evident that the concept had merits, but future studies will need to concretely examine more about the specifics of their preferences. This should eventually provide an expansion to the current understanding of this user group and its preferences in relation to the correct use of the medium.

An interesting aspect to the content of this paper is the degree of interpretation that can be placed on whether landmarks should in fact only be man-made to be easily recognized and memorable. As Vinson seems to address urban settings more than nature-based settings, significant natural content *could* serve as landmarks, if sufficiently distinct as an object, sufficient in size and appearance, and significantly noticeable from their surroundings. This indicates that it is up to the individual designer or design team to evaluate whether a landmark fits into the overall identity of the VE, what the landmark expresses and whether it will work for its intended purposes. In this sense, the division in the guidelines proposed in this paper, between the landmark typeset and the other factors such as virtual objects, “life”, etc., might open this discussion even further, once the guidelines are being put to concrete use in a future study.

This obviously leads to future works, where concrete examples of VE designs will give an impression on how to practically take the design guidelines into convincing custom made VE location. To further expand on the guidelines, more detailed considerations from game level design research, as creating multimodal expression and environmental experiences for the general public should be considered. Fields such as scenic beauty research and aesthetics research could prove very useful. Even so, the fields, which are in fact, addressed in the paper such as restoration, recreational tourism, urban design, urban planning, cognitive psychology and landmark research spans much further than what has been addressed in this paper.

Going forward, more work on these recreational VE designs should address issues such as these. Meanwhile, the current proposition of the Recreational VE Guidelines in this paper seems like a step in an interesting direction for this relatively novel field.

V. CONCLUSION

In this paper, we are proposing what will most probably only be the beginning of the *Recreational VE Design Guidelines*; a set of considerations and approaches found relevant when building custom VEs for recreational purposes –

in this case, for elderly users at nursing homes to augment a biking exercise. The guidelines are built from a literature review of relevant studies from different fields spanning recreational real world environments, VE design, and a landmark typeset originally used to facilitate effective navigation in VEs. For future works, the framework will facilitate the development of recreational VEs for nursing home users, who suffer from decreased memory capabilities. The guidelines need more research and testing, but the considerations seem useful.

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